LOI - Hadron Calorimetry

SiD Workshop at SLAC

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Overview

- HCal Introduction/requirements
- Overall HCal design
- Technology options -> Main points/figures for:

  RPC, GEM, Micromegas, Scintillator, Homogeneous dual-readout

- Issues/missing items/edits

Note: The initial drafts for each technology were a factor of 2-3 more than could be accommodated in the LOI. Reductions were made by me and again by the LOI editors…but needs some slimming down!

LOI - Hadron Calorimetry

Introduction to Calorimeters

To measure hadronic jets of particles produced in high energy collisions of electrons and positrons, with suffcient precision it is widely accepted that a new approach is necessary. The most promising method, called a Particle Flow Algorithm (PFA), utilizes both the tracking information for charged particles and the calorimeter for the measurement of the energy of neutral particles. PFAs applied to existing detectors, such as CDF and ZEUS, have resulted in significant improvements of the jet energy resolution compared to methods based entirely on calorimetric measurement alone. However, these detectors were not designed with the application of PFAs in mind. The SiD concept on the other hand accepts that a PFA is necessary and is designing the detector to optimize the PFA performance with the goal of obtaining jet energy resolutions of the order of 3% of E_{jet}.
The major challenge imposed on the calorimeter by the application of PFAs is the association of energy deposits with either charged or neutral particles impinging on the calorimeter. This results in several requirements on the calorimeter design:

. To minimize the lateral shower size of electromagnetic clusters the Moli'ere radius of the ECAL needs to be minimized This promotes efficient separation of electrons and charged hadron tracks.

. Both ECAL and HCAL have to have imaging capabilities which allow assignment of energy cluster deposits to charged or neutral particles. This implies that the readout of both calorimeters needs to be finely segmented transversely and longitudinally.

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. HCAL needs to be inside the solenoid to be able to do particle cluster association.

. In addition, the design of the calorimeter needs to be as uniform as possible, minimizing the use of different technologies, extendable to small angles to ensure hermeticity, and to provide enough depth for the longitudinal containment of hadronic showers. The design needs to consider the cost as an additional boundary condition.

Following is a short description of the baseline designs and options for the ECAL and the HCAL, as defined in December 2008.

An alternative approach to a PFA, based on homogenous crystal calorimetry, has recently been proposed. A description of this approach is also given later in this chapter.

HCal Introduction

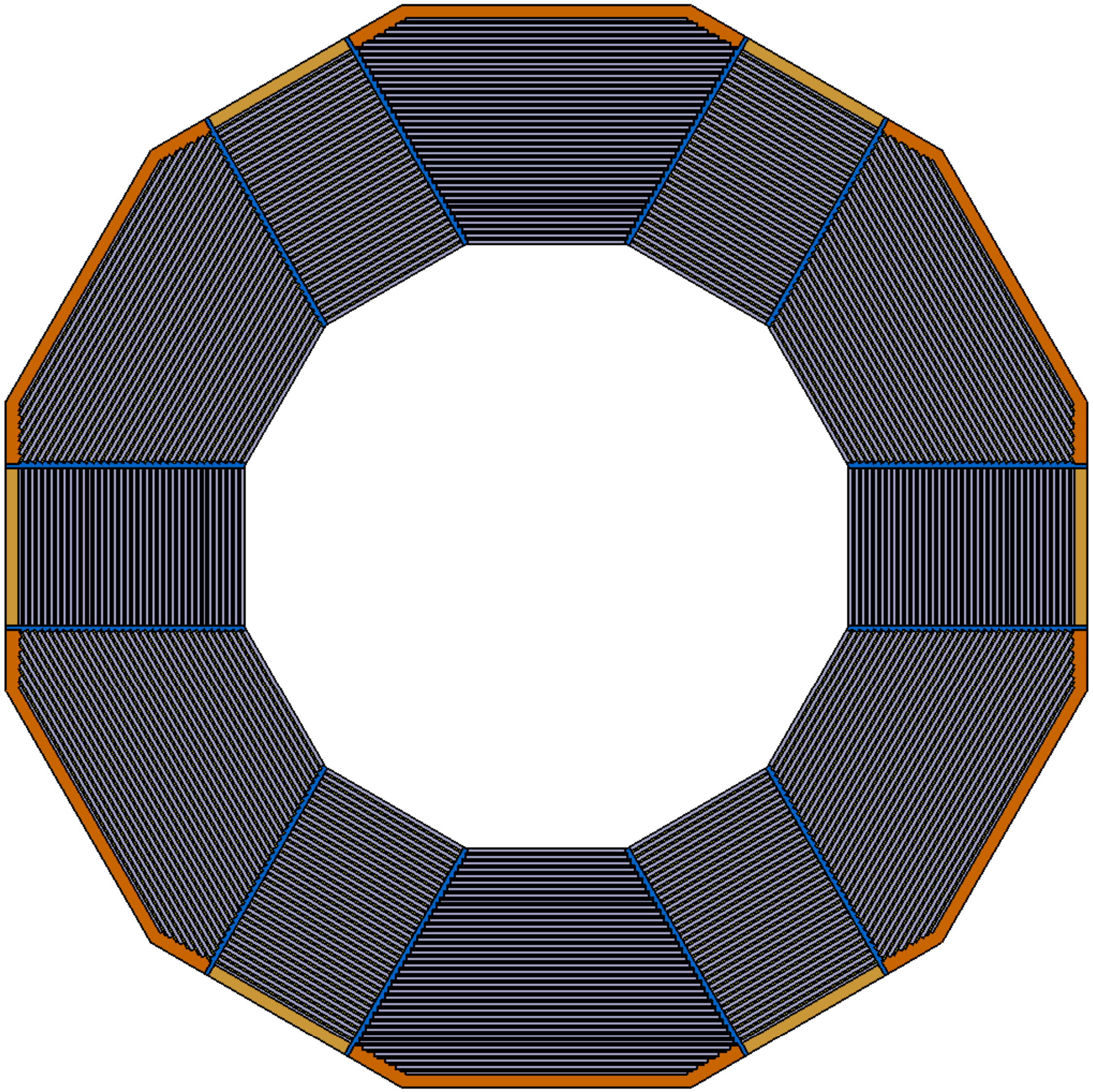
The PFA-based HCAL is a sandwich of absorber plates and instrumented gaps with active detector elements. It is located inside the magnet and surrounds the electro-magnetic calorimeter (Ecal), the latter being fixed to it. The total absorber depth amounts to 4.5 λ, made of stainless steel, divided into 40 layers, separated by 8mm gaps. Thus the HCAL internal and external radii are respectively: R_{int} =1419mm and R_{ext} =2583mm. The overall length is 6036mm long, centered on the interaction point.

The HCAL is divided into twelve azimuthal modules. In order to avoid cracks in the calorimeter, the module boundaries are not projective with respect to the interaction point. Consequently, in order to keep a symmetric shape two types of modules are used: 6 rectangles and 6 pseudo-trapezoids, as illustrated in Fig. ??.

Each module covers the whole longitudinal length. Chambers are inserted in the calorimeter along the Z-direction from both ends and can eventually be removed with out taking out the absorber structure from the magnet. Special care of the detector layout has to be taken into account to avoid a 90 degree crack.

The absorber plates are supported by several stringers fixed radially on both sides of the modules. Stringers of two consecutive modules are shifted in order to maximise the active detector area. Although the space between two consecutive modules is not instrumented, it is however filled by the absorber material. The barrel will be fixed on the magnet at 3 and 9 o'clock or 5 and 7 o'clock.

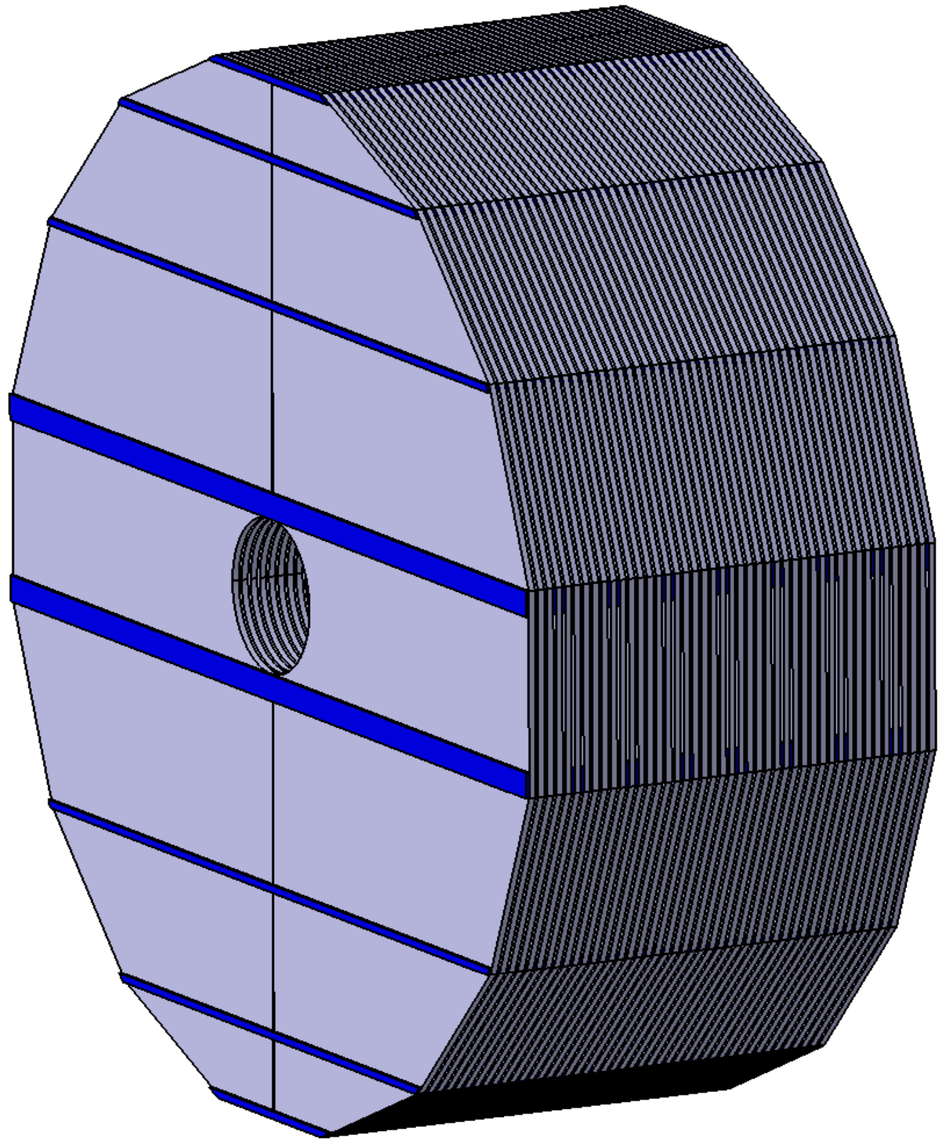
Cross-section of HCal Barrel



Alternating trapezoid/rectangle design with non-projective (filled) cracks

(Nicolas Geoffroy – LAPP)

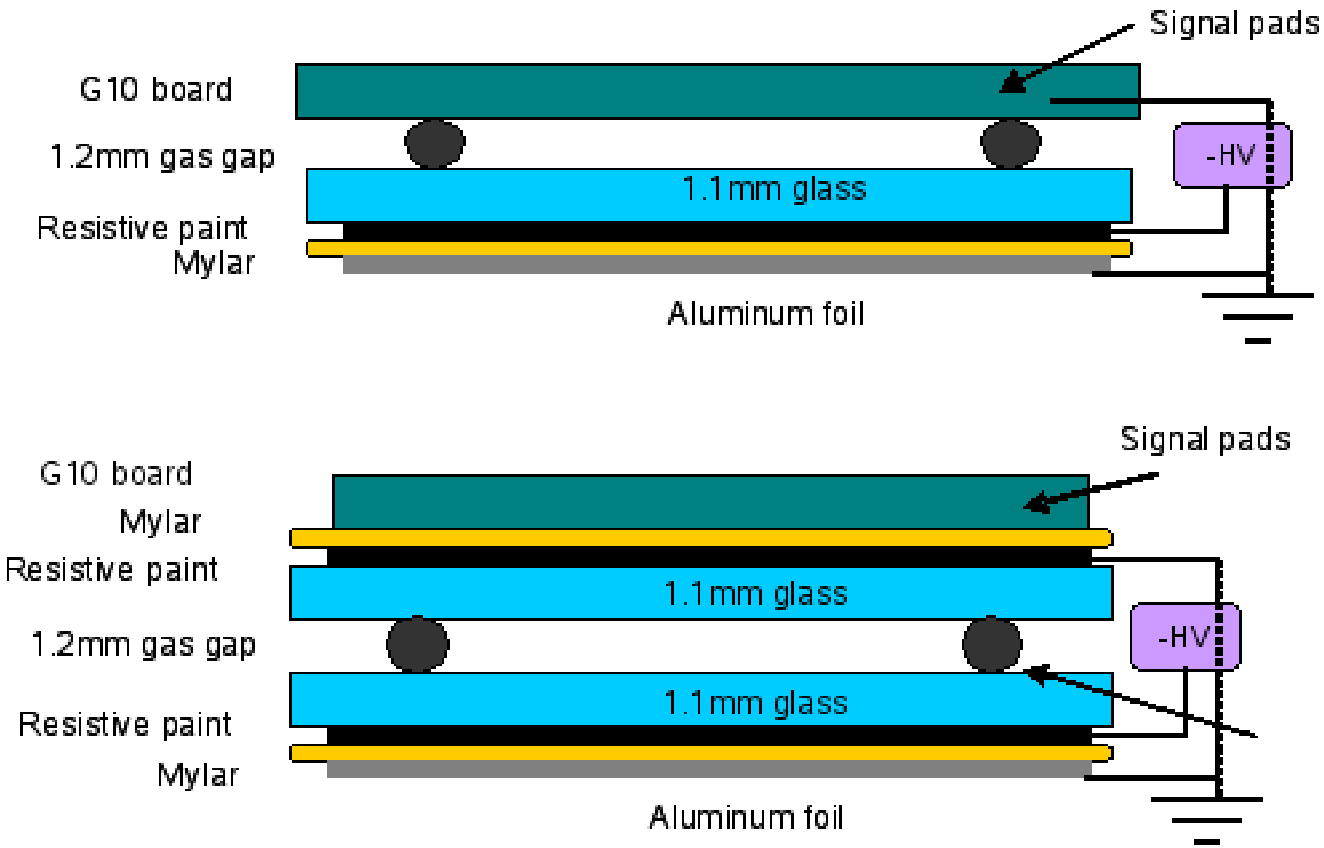
Cross-section of HCal Endcap



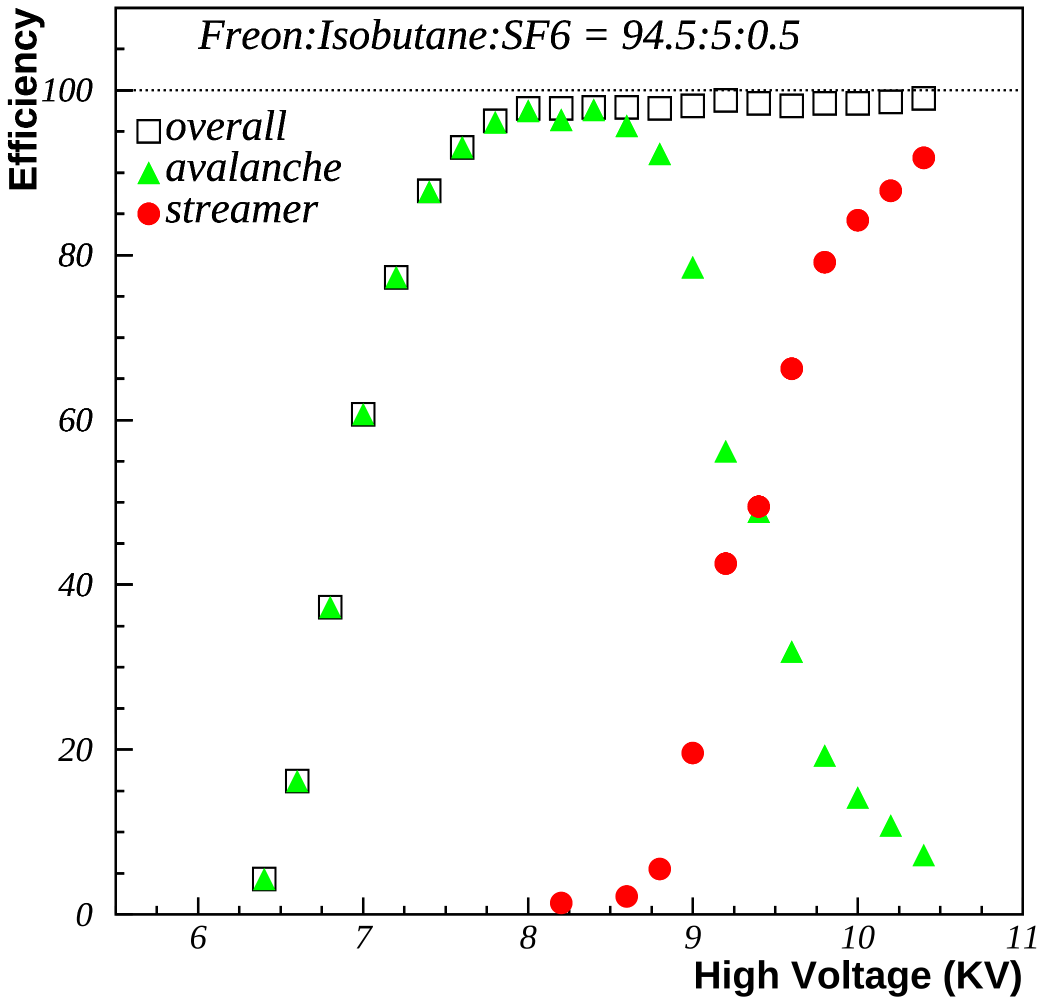
RPC HCal - Baseline

- Description of basic RPC operation
- 1, 2 glass designs
- Digital readout via pads
- Results from prototype chamber(s), characterization
- Results from vertical slice test
- Plans for 1m^3 stack, test beam
- Technical prototype

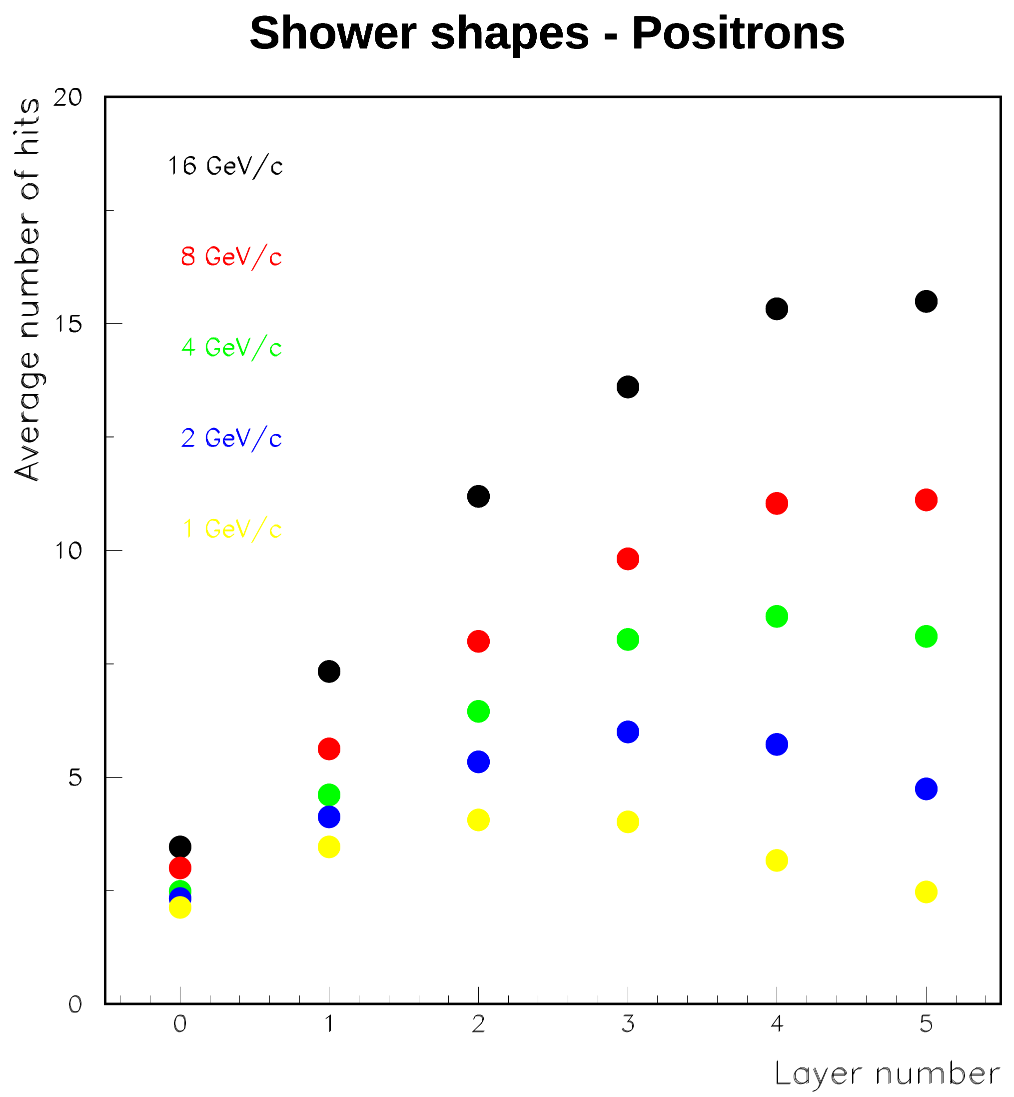
1, 2 glass RPC designs



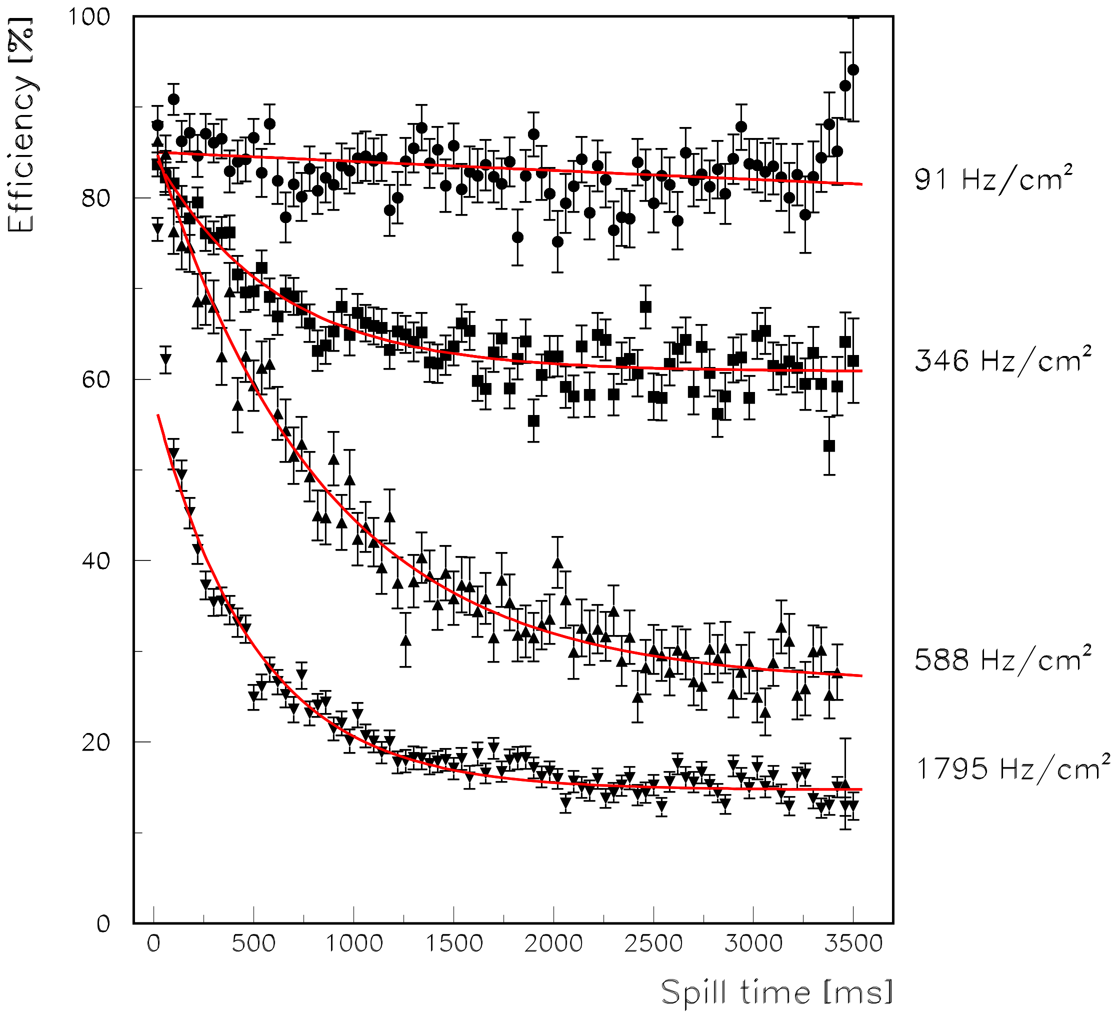
Results from prototype chamber characterization



Example of results from vertical slice test



Rate dependency for RPC chamber



$1m^3$ Prototype Stack and Technical Prototype

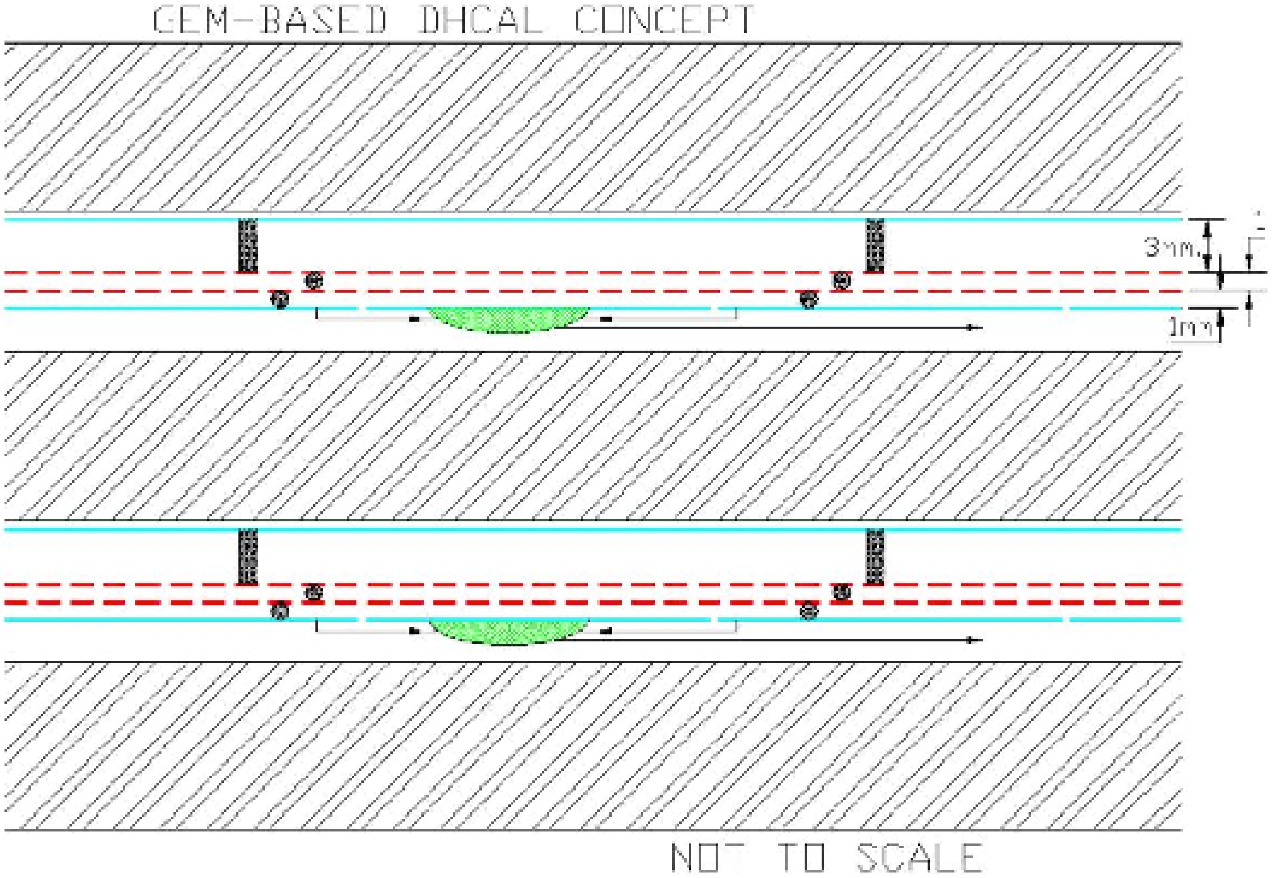
Group is currently assembling a larger prototype calorimeter with 40 planes and approximately 400,000 readout channels. The completed calorimeter will be tested in the Fermilab test beam in standalone mode and also together with the CALICE Silicon-Tungsten electromagnetic calorimeter. The tests will validate the concept of a digital hadron calorimeter with RPCs as active medium and make precision measurements of hadronic showers with unprecedented spatial resolution, to be confronted with various models of these showers.

The projected R&D for the module/technical prototype will initiate in 2010, after the completion of the construction of the large prototype calorimeter. This phase is expected to last 2-3 years.

GEM/DHCAL technology

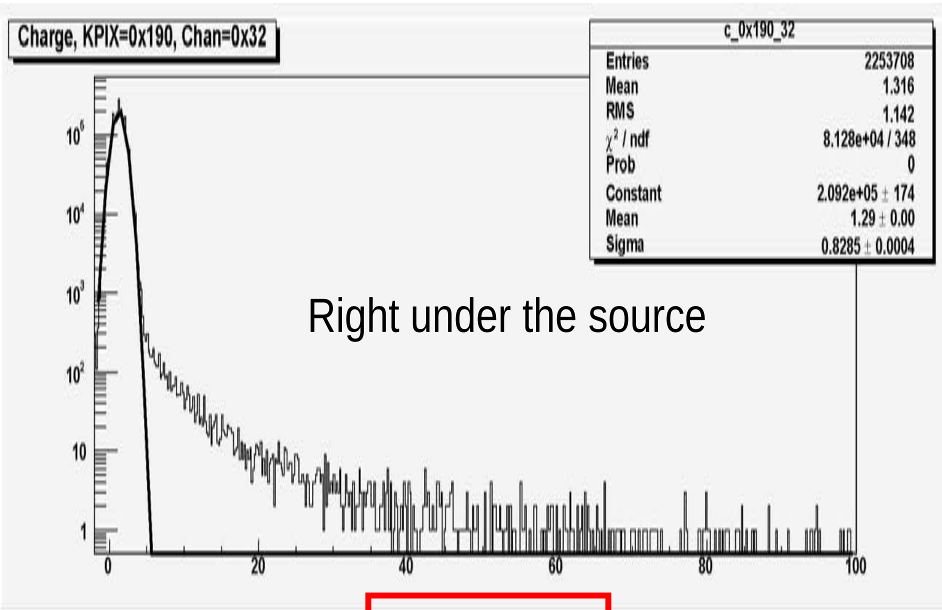
- GEM/DHCAL schematic
- Initial prototype tests, foil development
- Beam tests with 30cm x 30cm chamber(s)
- Working with the KPiX chip
- Towards 1m x 33cm chambers and 1m x 1m planes
- Thick-GEM alternative

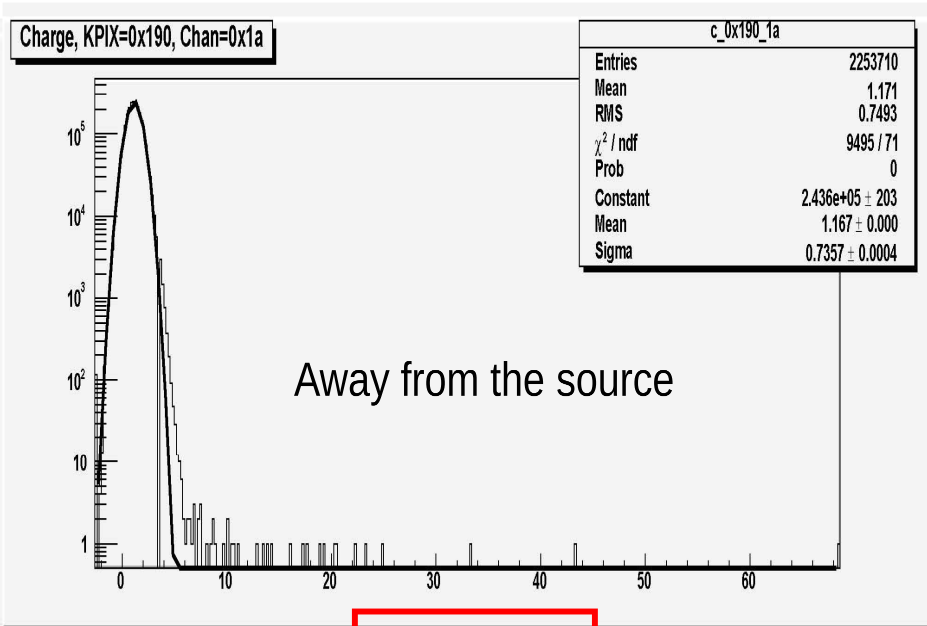
GEM/DHCAL schematic



30cm x 30cm foil developed with 3M

Example of results from tests of GEM with KPiX





fC scale

fC scale

GEM/DHCAL – next steps

Current year goals

– complete new 30cm x 30cm prototype + KPiX readout characterization (many features of KPiX understood)

- construct 1m x 33cm chamber using foils developed with CERN/RD51-MPGD.

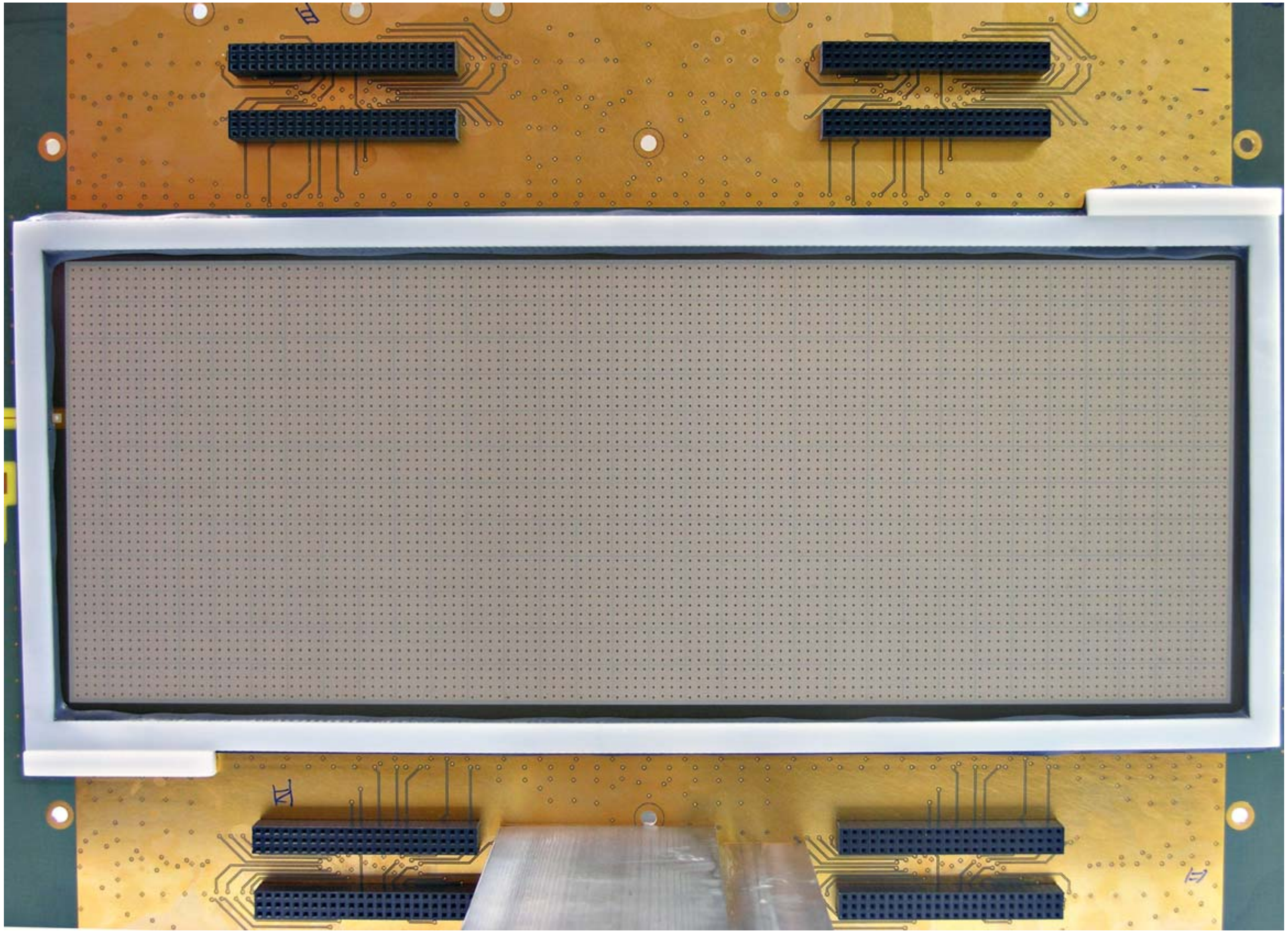
- complete design/start assembly of 1m x 1m planes.

- plan inclusion/testing of multiple 1m x 1m layers in $1m^3$ stack

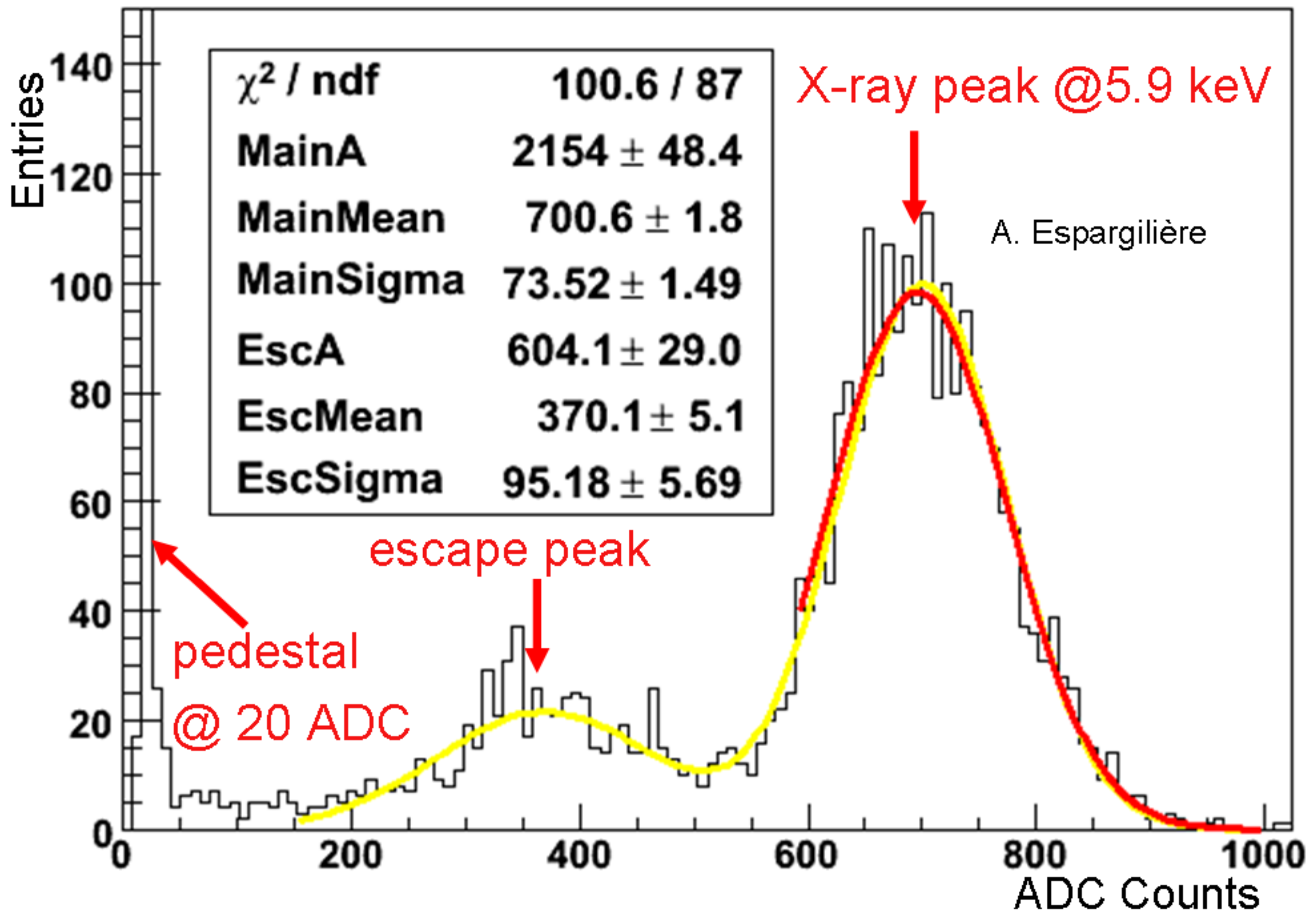
Micromegas technology

- First prototypes 6cm x 96cm and 12cm x 32cm
- Two chips: HARDROC (baseline for European 1m^3 DHCAL), DIRAC (longer term)
- Gain measurement from ^{55}Fe source
- Summer 2008 – 4 prototype "stack" at SPS/200GeV μ's
  - -> chamber mappings, efficiencies, noise
- DIRAC prototype with PCB/embedded chip in beam
- 1m^2 prototype -> eventual 1m^3 stack.

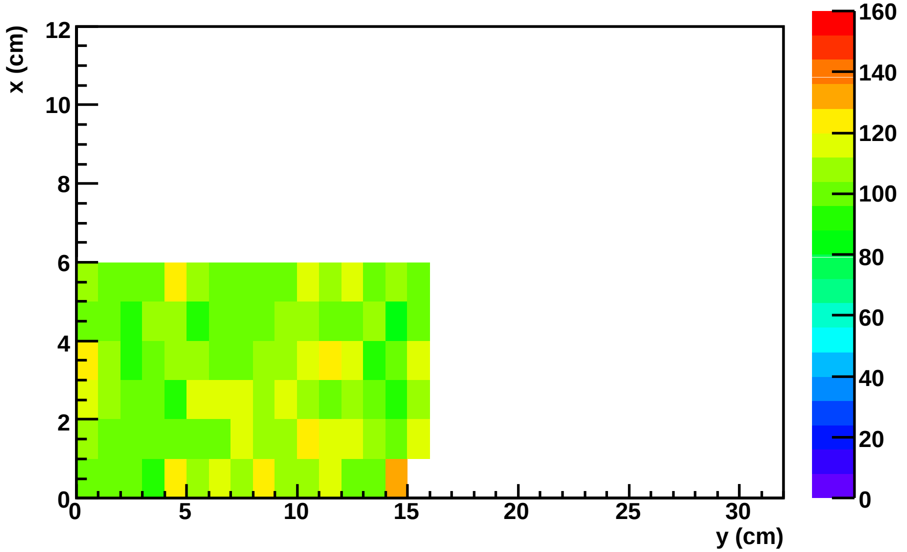
12cm x 32 cm first protoype micromegas chamber

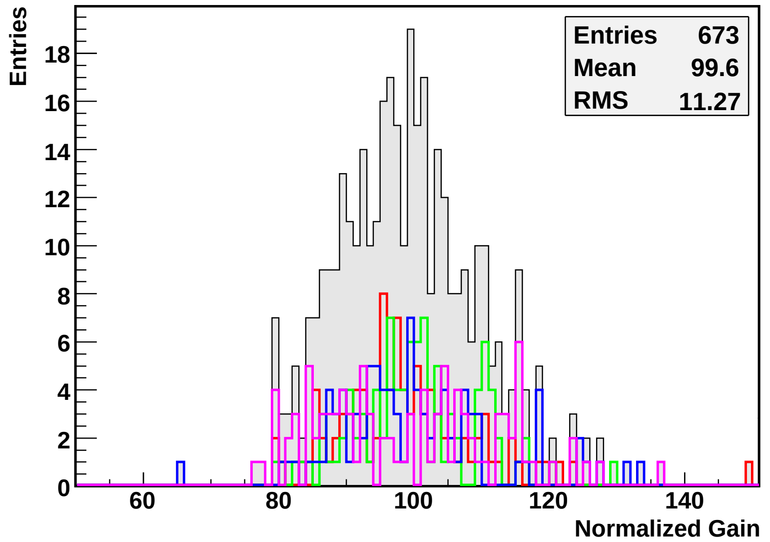


Micromegas analog response to ^{55}Fe source

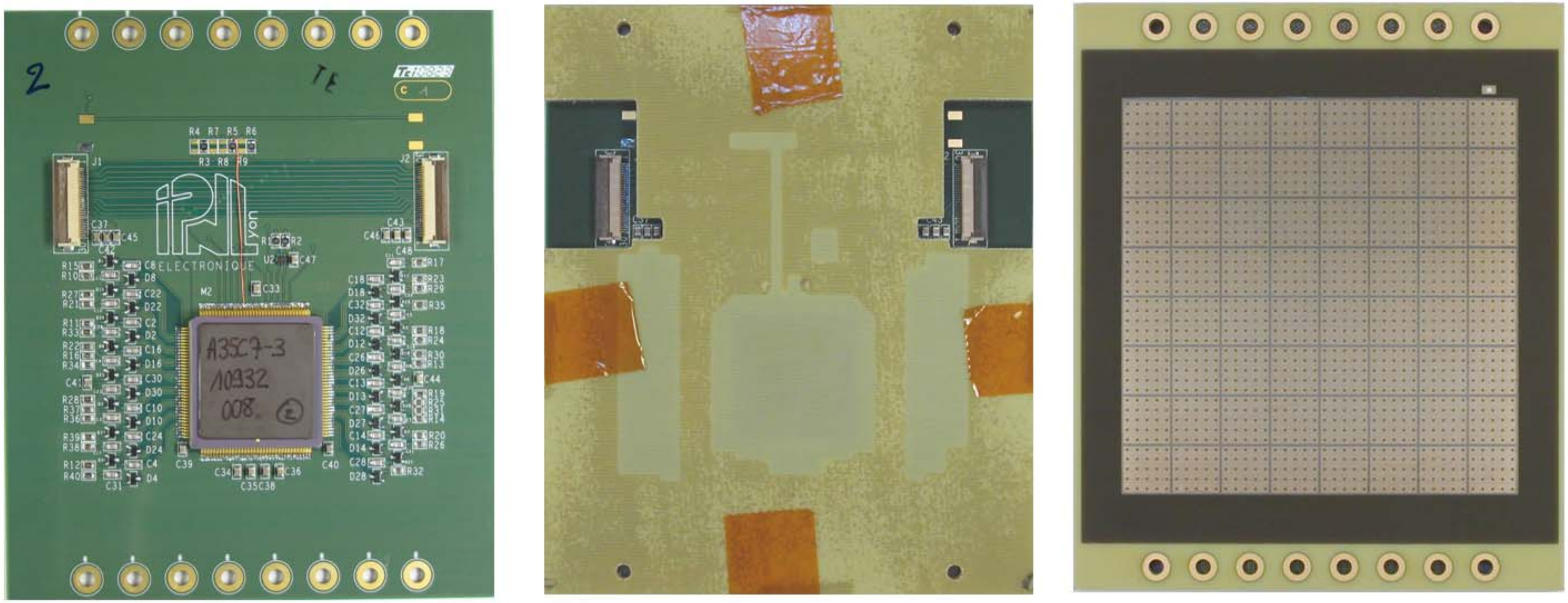


Micromegas chamber mapping with analog readout from CERN test beam



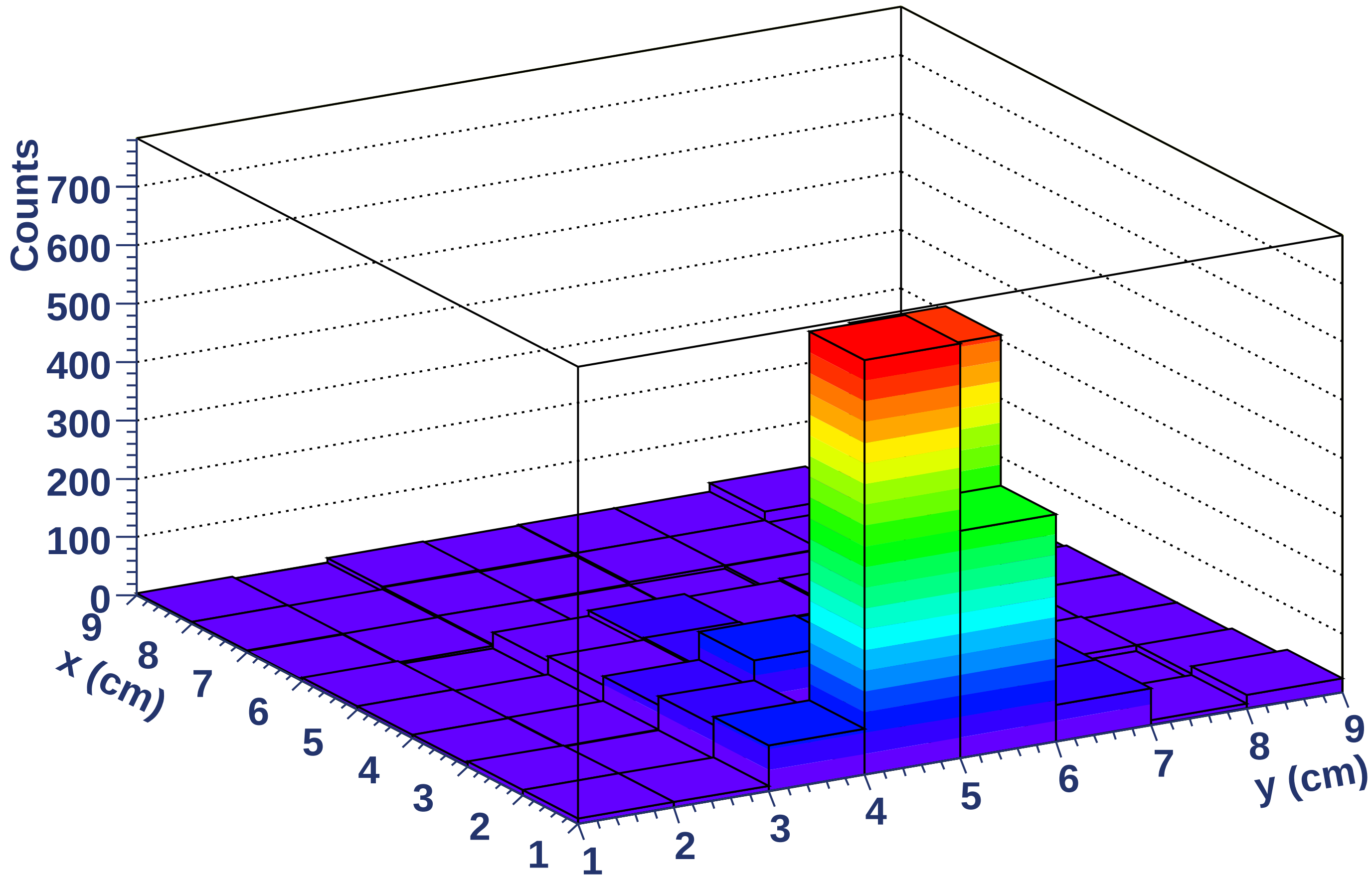


Prototype micromegas with DIRAC digital readout

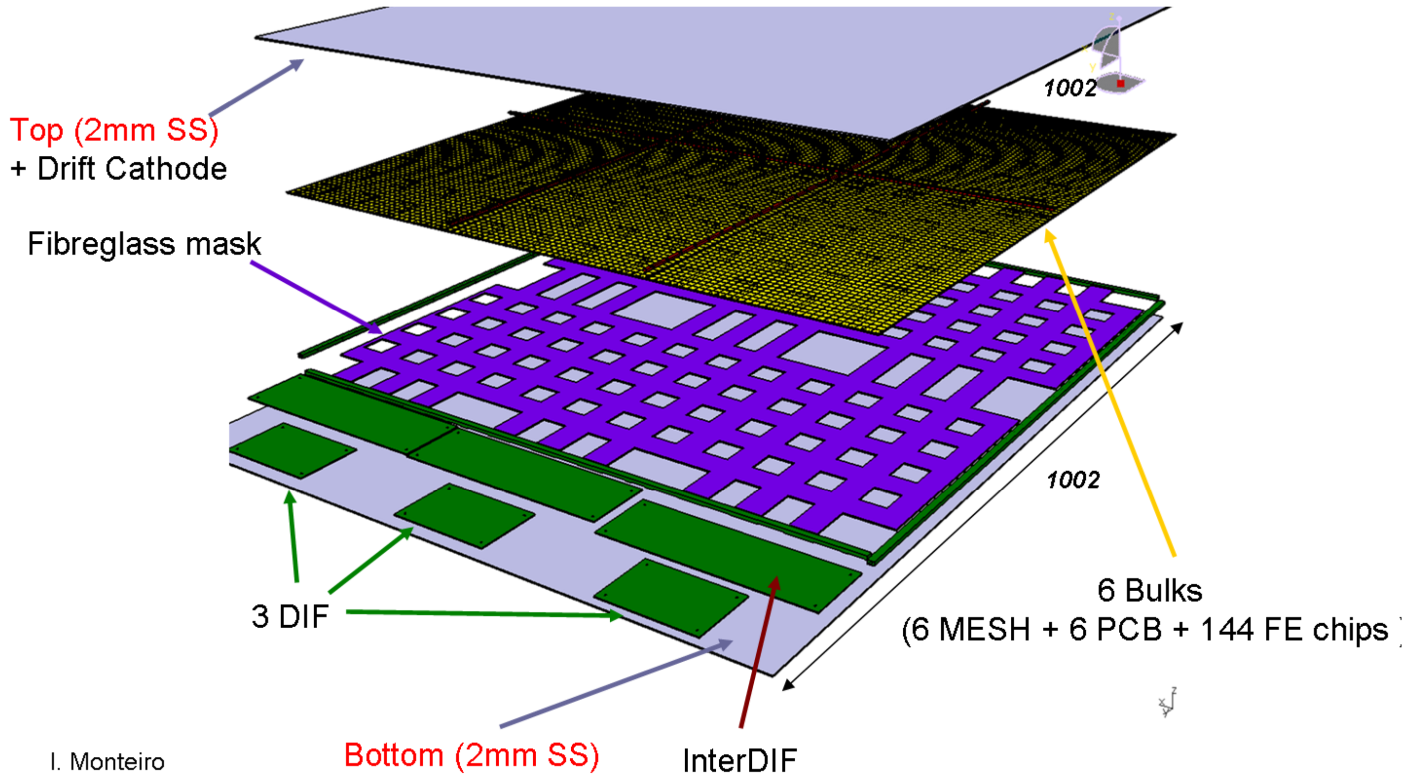


ASIC side, ASIC side with mask for bulk laying and pad side with bulk

Mapping of micromegas/DIRAC in 200 GeV pion beam, CERN Summer 2008



Design of 1m² micromegas prototype



I. Monteiro

Scintillator/SiPM technology

- CALICE 1m^3 prototype stack in 2-180 GeV/c test beams at CERN in 2006-8

  -> large samples of e- ,e+, π, p, μ events recorded

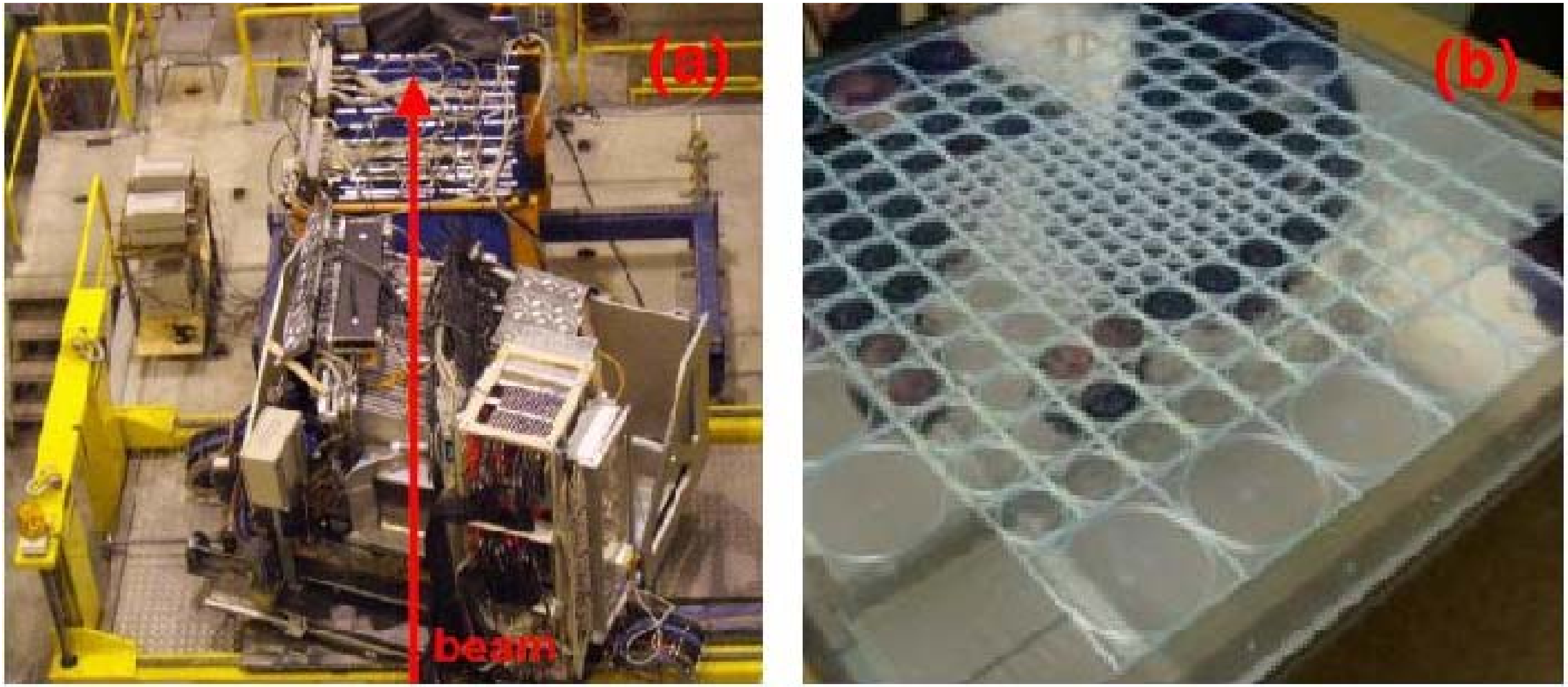
  -> analyses ongoing

- Development of integrated readout layer

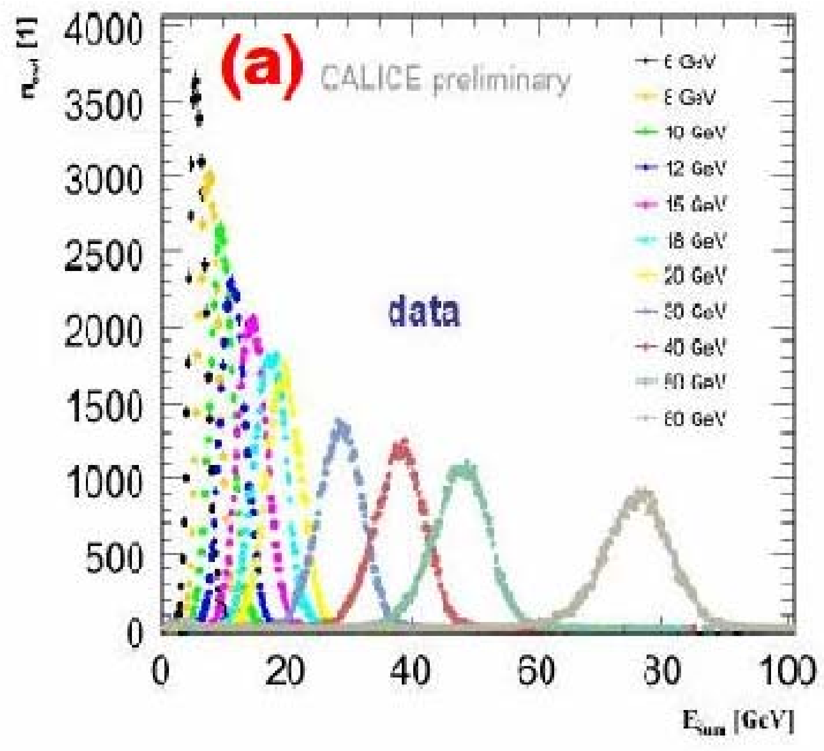
- Direct coupling (SiPM/tile) studies

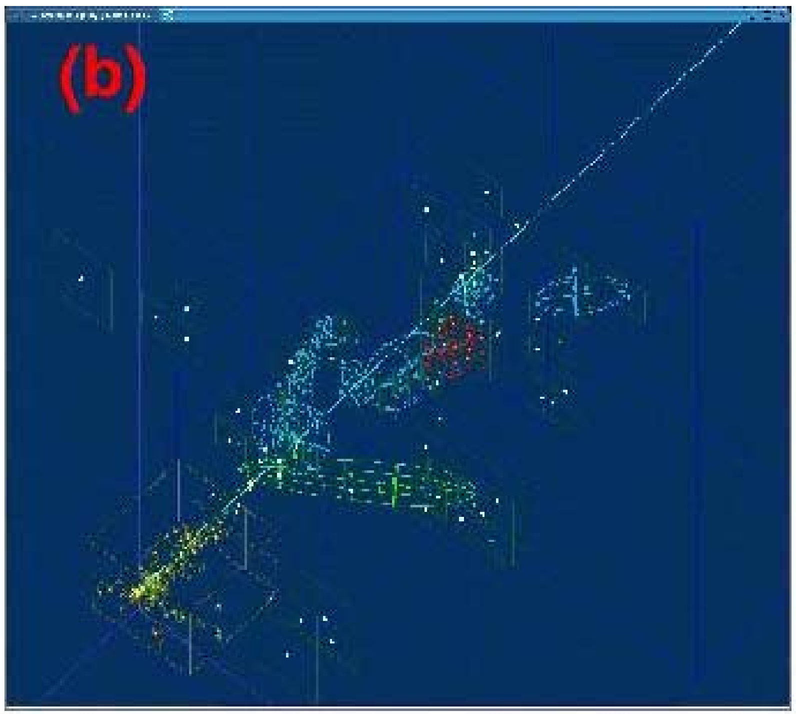
- EUDET/CALICE "technological" prototype – 2010 ->

CALICE testbeam setup at CERN + active layer

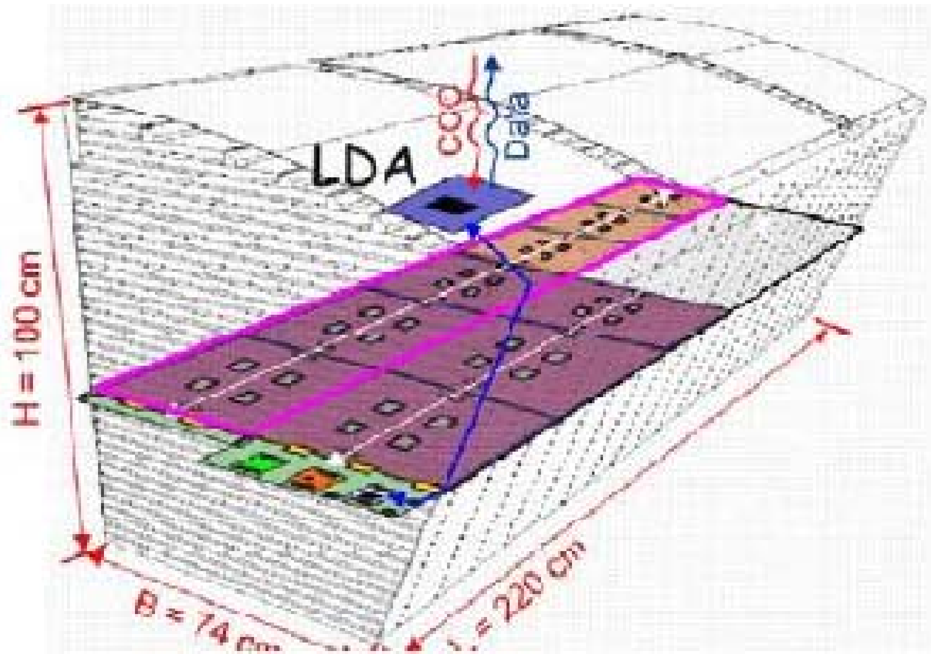


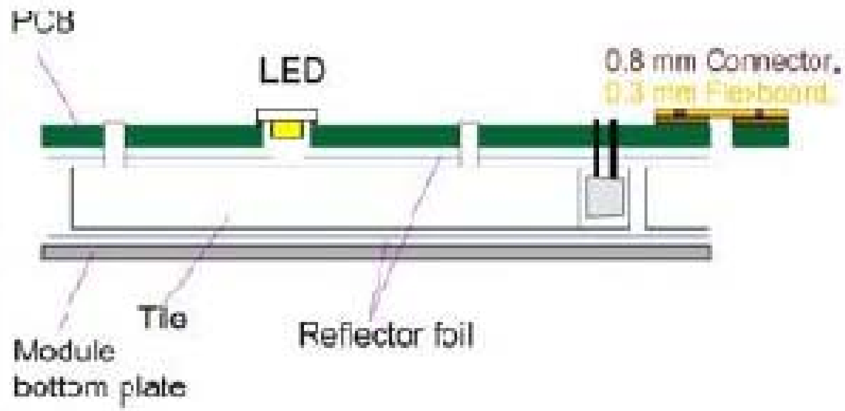
Response of 1m^3 stack to charged pions and view of stack imaging abilities.



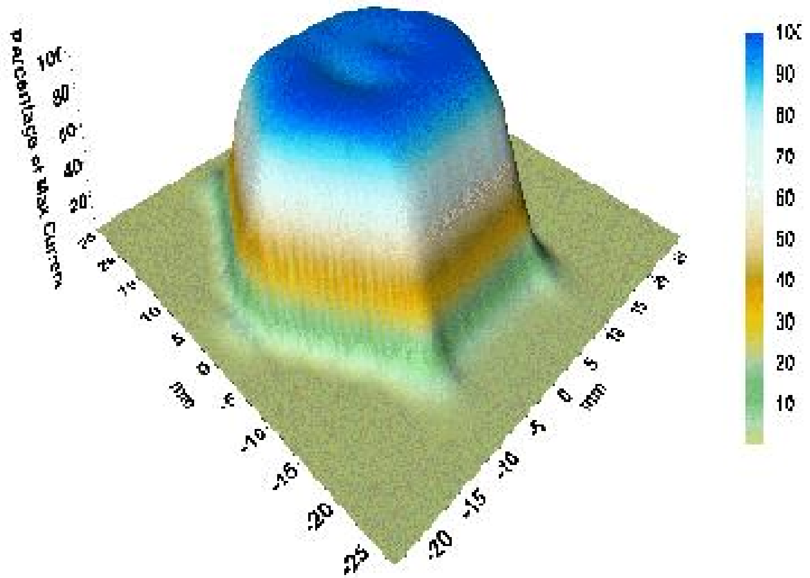


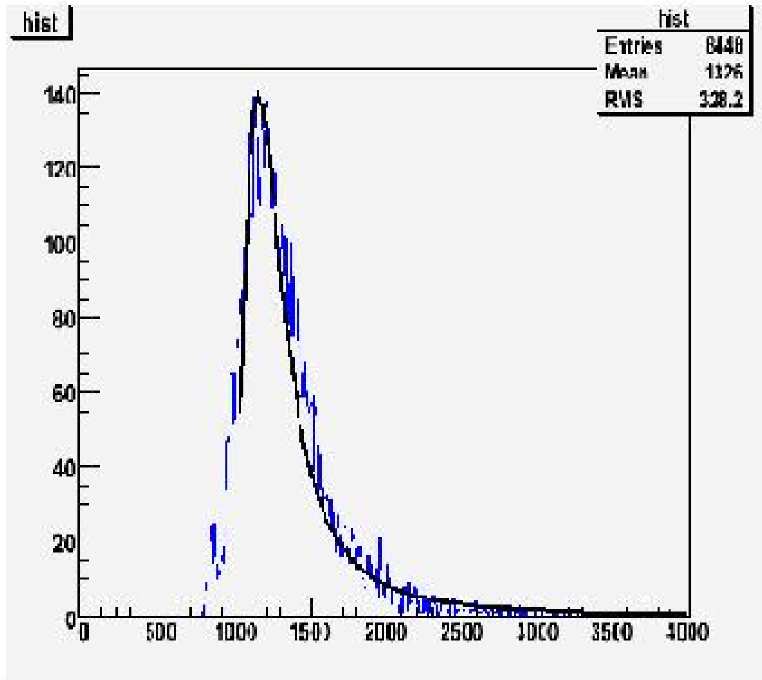
Schematic of barrel wedge with integrated readout





Response uniformity and muon response

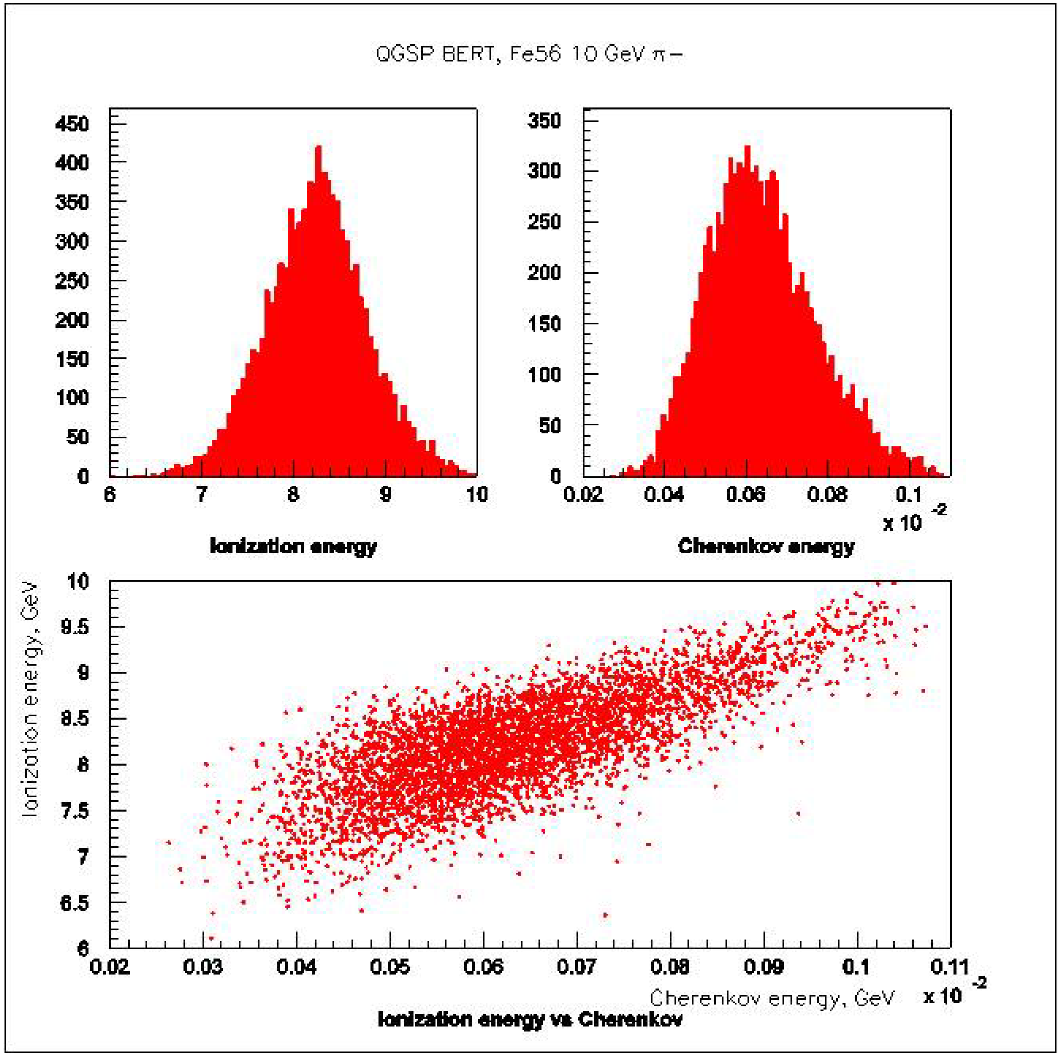




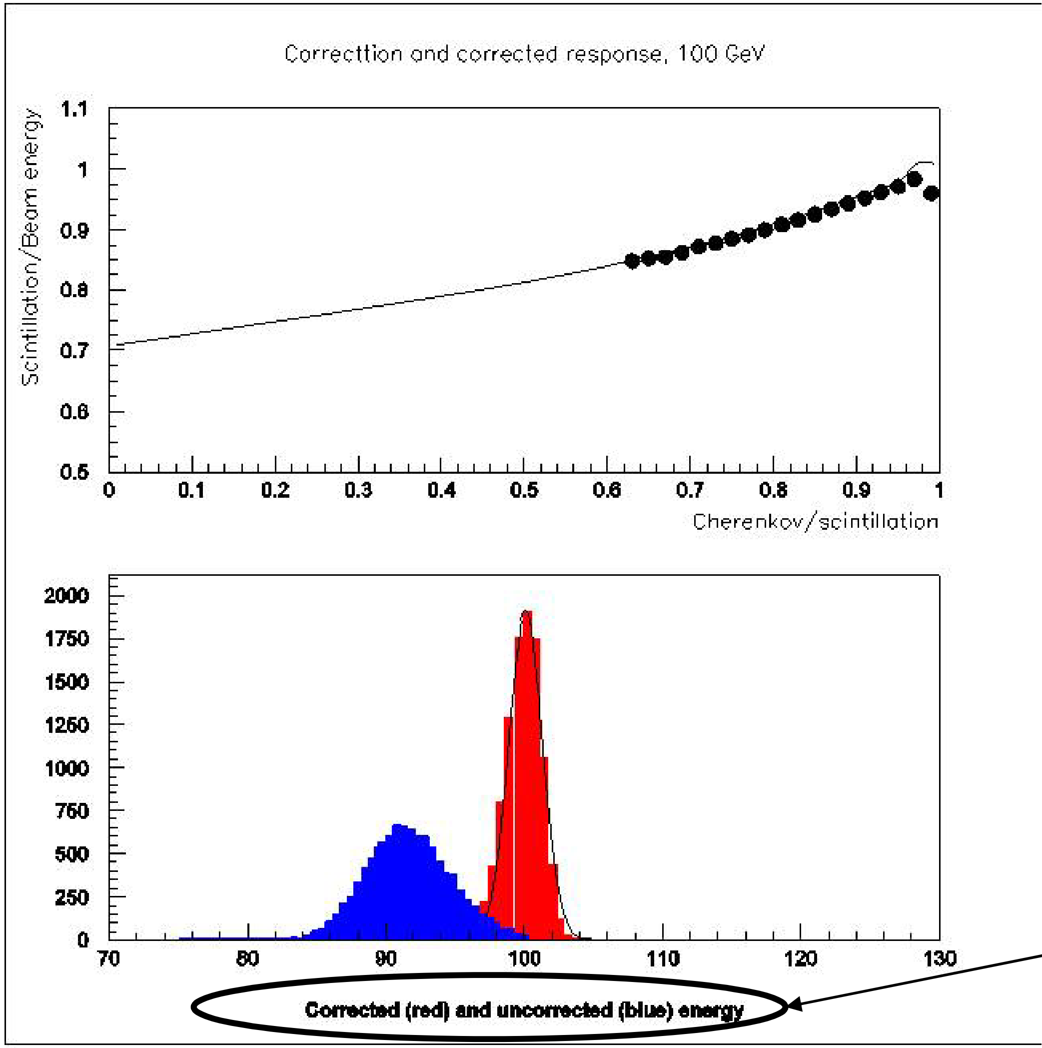
Homogeneous/Dual-readout technology

- Introduction – limitations on hadron energy resolution
- Elimination of limitations, use of correlation function
- Results of use of correlation function
- Enabling technologies (crystals and APD/SiPM)
- Conceptual design of HRC (High Resolution Calorimeter)
- Required R&D tasks

Total Ionization and Cherenkov signals and correlation



Dimensionless anti-correlation function and result of its use for 100 GeV pion in total absorption calorimeter



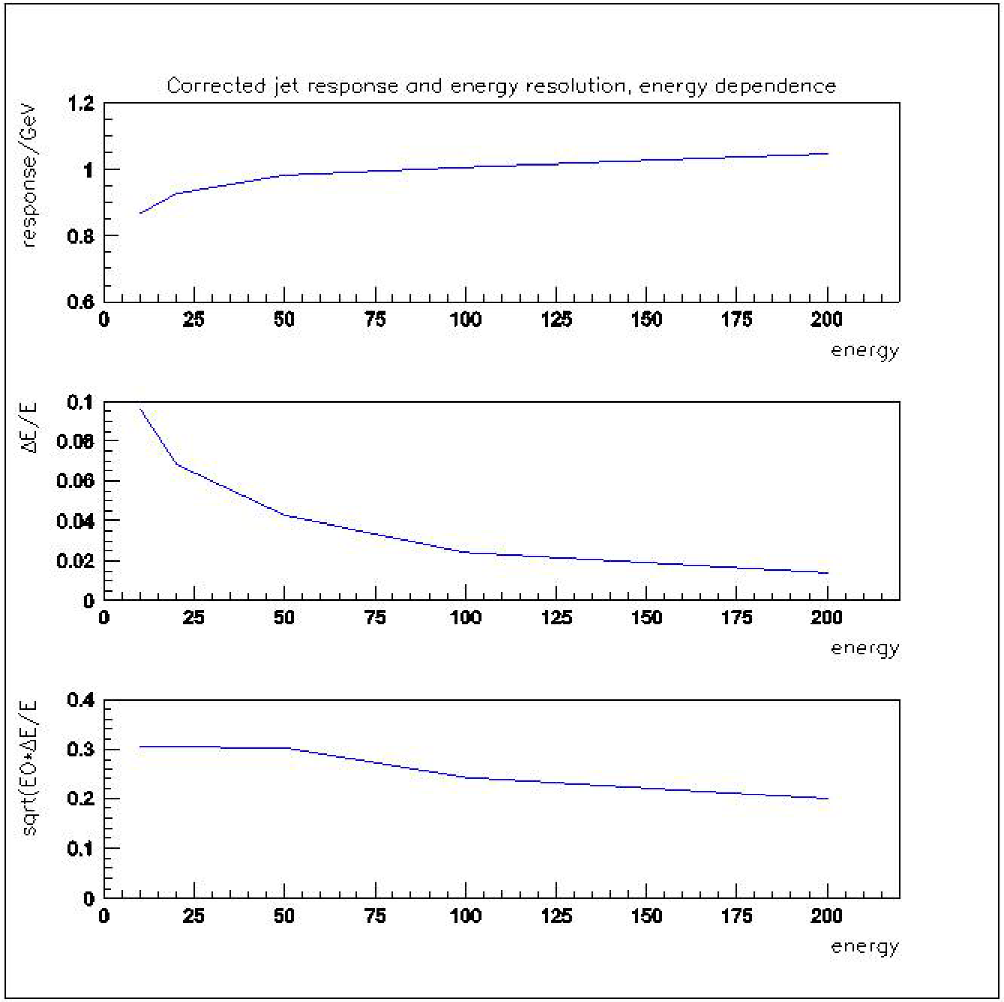
Plot average S/Ebeam as a function of C/S

- Fit some correction function F(C/S) (for example polynomial)
- Re-analyze the data:

– E = Asc*S/F(C/S)

Need to fix label!

Linearity, energy resolution, scaled energy resolution for hadronic jets



Homogenous Dual-Readout: R&D tasks

Five R&D tasks identified:

1) Demonstrate good linearity/energy resolution for hadrons in test beam
2) Optimize detector performance
3) Develop engineering design of detector/support
4) Development of novel, inexpensive optical materials
5) Development of compact photodetection system + electronics.

Other issues

Missing pieces:

- Calorimeter performance – draft exists
- R&D chapter contribution – to be worked on this week

Overall: We have more than enough material!

Need to work on:

- reduction in length
- even out lengths of technology sections
- more coherence